of Biomechanics 62 (2017) 39–46. https://doi.org/10.1016/j.jbiomech.2016.10.019
[4] L. Wade, L. Needham, P. McGuigan, J. Bilzon, Applications and limitations of current markerless motion capture methods for clinical gait biomechanics, PeerJ 10 (2022), e12995. https://doi.org/10.7717/peerj.12995
[5] E. Parrilla, A. Ballester, F. Parra, A. Ruescas, J. Uriel, D. Garrido, S. Alemany, MOVE 4D: Accurate High-Speed 3D Body Models in Motion, Proc. 3DBODYTECH 2019 - 10th Int. Conf. Exhib. 3D Body Scanning Process. Technol. Lugano Switz. 22-23 Oct 2019 (2019). https://doi.org/10.15221/19.030
[6] G. Wu, F.C.T. van der Helm, H.E.J. (DirkJan) Veeger, M. Makhsous, P. Van Roy, C. Anglin, J. Nagels, A.R. Karduna, K. McQuade, X. Wang, F.W. Werner, B. Buchholz, ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion—Part II: shoulder, elbow, wrist and hand, Journal of Biomechanics 38 (2005) 981–992. https://doi.org/10.1016/j.jbiomech.2004.05.042.
[7] A.V. Ruescas-Nicolau, H. De Rosario, E.P. Bernabé, M.-C. Juan, Positioning errors of anatomical landmarks identified by fixed vertices in homologous meshes, Gait & Posture 108 (2024) 215–221. https://doi.org/10.1016/j.gaitpost.2023.11.024.
[8] Klug A, Gramlich Y, Wincheringer D, Hoffmann R, Schmidt-Horlohé K. Epidemiology and Treatment of Radial Head Fractures: A Database Analysis of Over 70,000 Inpatient Cases. J Hand Surg Am. 2021 Jan;46(1):27-35. https://doi: 10.1016/j.jhsa.2020.05.029. Epub 2020 Aug 11. PMID: 32798123.

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The Movement Deviation Profile gives a speed-matched measure of gait deviation

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Introduction

Walking speed affects gait [1] and gait pathologies can alter walking speed [2]. Most commonly used gait indices (such as the GDI and GPS) compare pathological gait to a fixed reference [3,4]. Conversely, the movement deviation profile (MDP) [5] claims to calculate multidimensional gait deviation from a distribution of normality, including gait at a range of walking speeds.

Research Question

Can the MDP give speed-matched gait deviations by comparing patient gait to the normality distribution region that matches the patient's walking speed?

Methods

Normal gait (n = 80 trials of 10 controls) was captured at very slow (Vslow), Slow, Self-selected and Fast speeds (Vicon, Oxford, UK). Alkaptonuria (AKU) patient gait was captured (n = 574 trials of 62 patients aged 16-78 years) at self-selected speeds. Marker coordinates (Helen Hayes model [6]) were expressed relative to the line fitted on the centre of the pelvis [7]. Gait deviation (MDPmean) was generated for all normal trials using Vslow, Slow, Self-selected, Fast and All speeds of normal gait as reference. The MDPmean was also calculated for the 574 AKU trials in the same way, using the same five reference groups. For each walking speed that the MDP was trained on, second order polynomials were fitted to the resultant MDPmean values.

Results

The MDP gave the smallest deviation from normal gait at the speed the MDP was trained on (Figure 1a). Polynomial minima occurred at increasing speeds as the walking speed of gait used to train the MDP increased. The minimum value for the polynomial of the MDPmean values trained on all speeds was between slower and faster speeds (Vslow = 0.75m/s, Slow = 1.11m/s, All = 1.2m/s, Self-selected = 1.34m/s, Fast = 1.67m/s). Similarly, minima of AKU gait MDPmean polynomials occurred at increasing walking speeds as the walking speed used to train the MDP increased (Figure 1b). Again, the minimum value for the polynomial of AKU MDPmean values trained on All speeds occurred between slower and faster walking speeds (Vslow = 1.04m/s, Slow = 1.26m/s, All = 1.45m/s, Self-selected = 1.58m/s, Fast = 1.68m/s).

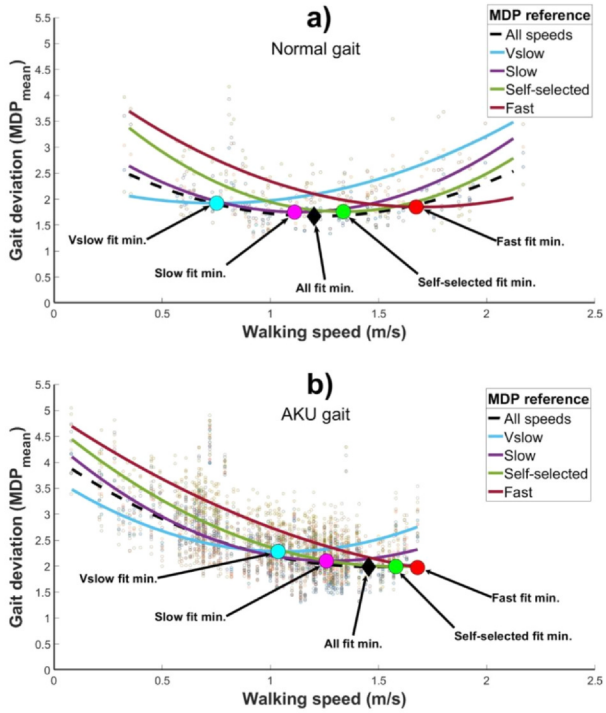

Figure 1. Values (scatter points) and fitted polynomials (curves) of the MDP_{mean} for each trial of (a) normal and (b) AKU patient gait where the MDP uses normal gait at All speeds (black), Vslow (blue), Slow (purple), Self-selected (green), and Fast (red) walking speeds as reference. Polynomial minima highlighted with circles (diamond for All).

Discussion

Using normal gait at different walking speeds as reference, the MDP's internal representation of normality more closely matches normal gait at those walking speeds. Trained on gait at all walking speeds, the distribution encompasses a broader span of normality, diminishing the effects of walking speed and emphasising the effects

of pathology. Normal and AKU MDPmean differences are due to the additional effects of pathology on AKU gait [7], most noticeable at slower speeds where AKU disease is more advanced. A self-organising neural network (the engine underlying the MDP) trained with normal gait at all speeds return speed-matched deviations of gait from normality. Such a single number gait index is expected to help clinical decision-making when patients walk with altered speeds as in alkaptonuria.

References

1. Stanfield, BW; Hazlewood, ME; Hillman, SJ; Lawson, AM; Loudon, IR; Mann, AM; Robb, JE. 2001. Gait is predominantly characterised by speed of progression, not age, in 5 to 12 year old normal children. Gait & Posture, 10(1), pp.1639-1650. https://doi.org/10.1016/j.jbiomech.2008.03.015
2. Theis, KA; Murphy, LB; Baker, ScD; Hootman, JM. 2019. When You Can't Walk a Mile: Walking Limitation Prevalence and Associations Among Middle-Aged and Older US Adults with Arthritis: A Cross-Sectional, Population-Based Study. ACR Open Rheumatology, 1(6), pp.350-358. https://doi.org/10.1002/acr2.11046
3. Schwartz, MH; Rozumalski, A. 2008. The gait deviation index: A new comprehensive index of gait pathology. Gait & Posture, 28(3), pp.351-357. https://doi.org/10.1016/j.gaitpost.2008.05.001
4. Baker, R; McGinley, JL; Schwartz, MH; Beynon, S; Rozumalski, A; Graham, HK; Tirosh, O. 2008. The Gait Profile Score and Movement Analysis Profile. Gait & Posture, 30(3), pp.265-269. https://doi.org/10.1016/j.gaitpost.2009.05.020
5. Barton, GJ; Hawken, MB; Scott, MA; Schwartz, MH. 2012. Movement Deviation Profile: A measure of distance from normality using a self-organizing neural network. Human Movement Science, 31(2), pp.284-294. https://doi.org/10.1016/j.humov.2010.06.003
6. Davis, RB; Ounpuu, S; Tyburski, D; Gage, JR. 1991. A gait analysis data collection and reduction technique. Human Movement Science, 10(5), pp.575-587. https://doi.org/10.1016/0167-9457(91)90046-Z
7. Barton, GJ; King, SL; Robinson, MR; Hawken, MB; Ranganath, LR. 2014. Age-Related Deviation of Gait from Normality in Alkaptonuria. JMID Reports, 24, pp.39-44. https://doi.org/10.1007%2F8904_2015_431

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Frontal and transverse plane hip angles during walking vary between CGM2 and Plug-in-Gait models

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Introduction

In recent years the new Conventional Gait Model 2 (CGM2) has been introduced in the clinical gait analysis society (1). The CGM2.3 version, is intended to replace previous models like Plug-in-Gait (PiG) (2), which has been one of the standard models in clinical gait analysis for the last three decades. Besides introducing a more valid hip joint estimation algorithm, it is also designed to better withstand movement artefacts, a feature also intended by a PiG variant introduced by Wren et al (PiG_Wr) in 2008 (3). However, the adoption of CGM2.3 is hesitant among clinical gait laboratories, with one contention being the uncertainty surrounding comparisons between CGM2.3 data and previously gathered patient data utilizing PiG.

Research Question

To investigate differences in hip kinematics during gait between the standard PiG, PiG_Wr and the CGM2.3.

Methods

Twenty young, healthy women (age 17-30) were included. Markers for both PiG, PiG_Wr and CGM2.3 were mounted. For all three models, the thigh and shank planes were defined by aligning to medial knee- and ankle markers during a static trial. Three gait trials were collected, and marker trajectories were filtered with a Butterworth lowpass, with cutoff at 12 Hz. After data collection, the gait trials were copied to separate folders, and joint kinematics were calculated separately for each model. Subsequently, the hip joint angles were cropped and normalized to 100% of a gait cycle, before the root-mean-square difference (RMSD) between the three models were calculated for each anatomical plane.

Results

The results showed generally larger differences in the transverse plane than the sagittal plane (see table 1). The frontal plane proved very similar between the two PiG models, but larger differences when compared to the CGM2.3.

Table 1

Discussion

The study showed that the main difference between the CGM2.3 model and the PiG models were in the hip abduction/adduction angles. Leboeuf et al (4) also investigated the influence of the Harrington hip model used in CGM2.3 vs. the Davis hip model used in PiG, however showing slightly smaller RMSD of approximately 3° in the frontal plane. The considerable differences observed between the models in the transverse planes cannot be solely attributed to the utilization of different hip models. Given that transverse plane angles are particularly susceptible to movement artefacts, the observed differences may reflect varying resilience to these soft tissue oscillations. Consequently, substantial disparities between CGM2.3 and PiG models may be anticipated when comparing results in the transverse and frontal planes, whereas differences in the sagittal plane may be of lesser clinical significance.

References

1. Leboeuf F, Baker R, Barré A, Reay J, Jones R, Sangeux M. The conventional gait model, an open-source implementation that reproduces the past but prepares for the future. Gait Posture. 2019; 69:235–41.
2. Kadaba MP, Ramakrishnan HK, Wootten ME, Gainey J, Gorton G, Cochran GV. Repeatability of kinematic, kinetic, and electromyographic data in normal adult gait. J Orthop Res. 1989;7(0736–0266):849–60.